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tain, the results of domestication as affecting pectoral development is readily seen:

Ruffed grouse (*Bonasa umbellus*)	15.51	per cent.
Hen	4.66	"
Wild goose (*Branta canadensis*)	10.22	"
Tame goose	6.40	"

I do not claim that from this list the exact place of a bird can be given as to its power of flight, because other elements than the size of the pectoral muscles enter into this complex problem so as to preclude an absolute classification on the basis of pectoral development, yet I think that there is a relative variation expressed by the figures given in this list, and that when together with this element the other elements of flight are considered we can tell the place a bird should occupy in the scale of flight.

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GEOLOGICAL EXTINCTION AND SOME OF ITS APPARENT CAUSES.

BY A. S. PACKARD.

IN his Origin of Species, Darwin says: " The extinction of species has been involved in the most gratuitous mystery. Some authors have even supposed that, as the individual has a definite length of life, so have species a definite duration. No one can have marveled more than I have done at the extinction of species." Finally, he remarks, " Thus, as it seems to me, the manner in which single species and whole groups of species become extinct accords wells with the theory of natural selection. We need not marvel at extinction; if we must marvel, let it be at our own presumption in imagining for a moment that we understand the many complex contingencies, on which the existence of each species depends. If we forget, for an instant, that each species tends to increase inordinately, and that some check is always in action, yet seldom perceived by us, the whole economy of nature will be utterly obscured. Whenever we can precisely say why this species is more abundant in individuals than that; why this species and not another can be naturalized in a given country; then, and not till then, we may justly feel surprised why we cannot account for the extinction of any particular species or any group of species."

The fact of extinction is indeed not less marvelous than that of evolution, and one cannot in these days feel satisfied that the solution of the problem lies in the theory of natural selection, which accounts for the preservation of species rather than their origin or extinction. Mr. Darwin having been the means of bringing many naturalists to believe in the theory of descent, they are not to lie supinely on their backs, resting securely on the dogma of natural selection and cease from all attempts to investigate the cause of evolution, to cease building a foundation for the working of natural selection. On the contrary the search for the causes of the transformation of species will be carried on with more energy, thoroughness and success. The clews which we already have discovered will be followed up, and finally we shall, by means of observation in the field and experiment in the laboratory, wrest from nature the secrets of life and its origin, and of the phenomena of death and extinction, not only of species but of orders.

Extinction may be both slow and rapid, the causes of each being primarily dependent on slow or rapid changes in the environment. The object of this article is to endeavor to show that the extinction of species is intimately connected with geological changes. It is a meagre sketch or outline of the more salient facts and laws which appear to us to immediately bear upon this intricate and difficult subject.

In Palæozoic times the climate of the globe was far more uniform than now. The continents of the present day were then of much less extent, in fact archipelagoes rather than continents; the land-surfaces were of moderate height, and mountain ranges smaller and lower. While the land masses or embryo continents of the eastern and western hemispheres were more or less independent centers of evolutionary creation, there was on the whole a great uniformity of plant and animal life. Species were perhaps more cosmopolitan than now.

When at the end of the Coal period the process of continent-making and mountain-building became greatly accelerated, resulting in that stupendous crisis in American geological history, the upheaval of the Appalachian mountain system, there must have been some degree of differentiation or setting aside of portions of the then continent into distinct areas or basins bounded by mountains, inland seas and rivers, and some slight subdivision into local faunas. We know that there was a distinct coal basin, or series of them, for example in Arctic America, another in Northeastern United States, and in the Central States of the Upper Mississippi valley.

Other crises, extending over comparatively brief periods of geological time, however long when measured by centuries, were the elevation of the Rocky mountains, of the Wasatch, the Uintah ranges, the Sierra Nevada and Cascade ranges; and, meanwhile, the union of the Atlantic moiety and the Pacific moiety of our continent into a continuous land-mass. These periods of activity, signalized by extensive volcanic outpourings and great changes in the relative distribution of land and sea, must have been, as palæontology shows, periods of rapid extinction as well as of reparation or recreation. Progress in continent-making was accompanied by progress and an onward sweep in the tide of life, not only in animals with jointed bodies and limbs, but more especially in those with back bones and brains to correspond with their vertebrate rank.

Until the end of the Tertiary period the earth's climate was still nearly uniform. There was through the Miocene a general, indeed most remarkable resemblance between the flora of Europe and the United States, with that of Greenland and Spitzbergen, or the regions now lying in the frigid zone; this flora being in some respects like that of Louisiana.

It was not until the Glacial epoch that the earth's climate became differentiated into tropical and frigid and temperate zones. That great geological crisis, whether due to astronomical or geological causes, or both combined, by which over enormous tracts of land in Northern and Central Europe, and Northeastern America a frigid climate, with continental glaciers, was spread—that crisis produced results on the life of the glaciated region which we can easily appreciate. The extinction of life over the stated areas became widespread. The incoming of the Ice age also must have induced extensive migrations to the southward. As the glaciers melted, and the climate ameliorated, fresh migrations from the south set in, and thus in the early Quaternary period, when species were exterminated on a vast scale by causes readily appreciable, we have set before us, in a language which every one can translate, some of the geological causes of extinction, modification and consequent evolution of new forms.

We will begin, then, with a reference to the changes in the life of the northern and southern hemispheres due to the glacial period. They are so familiar to the general reader that they need not detain us long.

By the end of the Tertiary period the northern regions, including the land around the north pole, viz: Spitzbergen, Novaya-Zemlya, Siberia, Greenland, together with Northern Europe and Northeastern America, must have abounded in life. Forests of trees, deciduous, evergreen and palmaceous, in their general appearance resembling those of Louisiana, spread like a mantle over the land, bordering the vast Tertiary lakes and sheltering herds of herbivorous mammals, such as deer, oxen, mammoths, which were attended by packs of dogs, or by solitary secretive cats prowling through the forest glades, waging war on the weak and defenceless or scattered ruminants.

This rich assemblage of mammalian life, with countless species of insects, and other invertebrate organisms, land, fresh-water and marine, was swept away. A large proportion died outright, perhaps a larger proportion migrated southward; a very small per centage survived. The mammoth and mastodon lived on, adapted themselves to the great change of climate, but just as the ice had passed away and the climate had ameliorated, and when the condition of life seemed more favorable, they succumbed. The Arctic bear, fox, lemming and hare, with the white ptarmigan and snowy owl, by adaptation to a snow-clad land survived, so to speak, the change, or rather, they are the descendants of species so plastic that they became modified, and adapted to an Arctic life. Even man, who appeared in the old world before or about the time of the incoming of the ice, not only followed the retreat of the glaciers, but adopted a strange sort of existence in a region where the climate has a mean annual temperature of less than 32° F. Wherever the Eskimo lived he found the walrus and seal, the modified relatives of the sea lions and sea elephants of other parts of the world. The profusion of Tertiary insect life was succeeded by a scanty assemblage of Arctic butterflies, moths, bees and other stragglers from the temperate regions.

The forests died outright, and where Sequoia, the sweet gum, the palm and other luxuriant semi-tropical trees flourished, now grow the dwarfed birch, willows and low herbs of Alpine and Arctic barrens. It is sufficiently manifest that the circumpolar flora and fauna are the dwarfed, or otherwise modified descendants of the Pliocene-Tertiary life of the same regions. Again, peculiarities in the distribution of plants and animals in North America and Northern Eurasia indicate strongly that there was an extensive migration southward down the Atlantic and Pacific borders of the continents as the glacial cold crept over the once populous circumpolar regions.

A second series of causes of extinction arose from the elevation or depression of extensive regions of the earth. The paroxysmal, elevatory process in the formation of the Cordillera of North, and particularly South America, involved corresponding more or less rapid changes in the flora and fauna of the Pacific Coast regions of those continents. In South America, particularly, during the Quaternary period, though there was no glacial period north of Patagonia, the extinction of life was widespread and marked.

As observed by Darwin and Alexander Agassiz, within historic periods there have been paroxysmal upheavals over thousands of square miles, if not over the whole extent of the Western Andean plateau.

For example, in 1822, after an earthquake, the coast line of Patagonia and Chili was suddenly elevated from two to seven feet above the level of the ocean. In 1835 Darwin, while at Valdivia on the coast of Chili, experienced the earthquake which devastated Conception, and he says his " compassion for the inhabitants was almost instantly banished, by the surprise in seeing a state of things produced in a moment of time, which one was accustomed to attribute to a succession of ages. In a single day, Feb. 20th, this earthquake shook the coast of South America over an area of 600,000 square miles, and the whole coast line of Chili and Patagonia was elevated from two to ten feet above the sea level." Darwin in his Voyage of a Naturalist remarks: " At the island of S. Maria (about thirty miles distant), the elevation was greater; on one part, Captain Fitz Roy found beds of putrid mussel-shells *still adhering to the rocks*, ten feet above high-water mark; the inhabitants had formerly dived at low-water spring-tides for these shells. The elevation of this province is particularly interesting from its having been the theatre of several other violent earthquakes, and from the vast numbers of sea-shells scattered over the land, up to a height of certainly 600 and, I believe, of 1000 feet. At Valparaiso, as I have remarked, similar shells are found at the height of 1300 feet; it is hardly possible to doubt that this great elevation has been effected by successive small uprisings, such as that which accompanied or caused the earthquake of this year, and likewise by an insensibly slow rise, which is certainly in progress on some parts of this coast." Darwin adds: "Two years and three-quarters afterwards, Valdivia and Chiloe were again shaken, more violently than on the 20th [Feb. 20, 1835], and an island in the Chonos archipelago was permanently elevated more than eight feet."

As observed by Mr. A. Agassiz, there are sea corals of species still living in the Pacific ocean adjacent, attached to the surface of interstices in the rocks at Tilibiche, Peru, at a point about 2900 feet above the level of the sea. This locality is situated on a ridge parallel to the coast, there being a pampa or basin between this ridge and the coast range. This basin was probably the bottom of an internal sea which afterwards became a salt lake, and was eventually drained into the Pacific by the breaking through of the mountain barriers. The extensive saline basins on the western slope of the Andes, at an elevation of over 7000 feet, may have been former ocean bottoms. In his Andes and the Amazon, Orton says: "President Loomis of Lewisburg University, Pa., informs the writer that in 1853, after nearly a day's ride from Iquique, he came to a former sea-beach. It furnished abundant specimens of Patellæ and other shells, still perfect, and identical with others that I had that morning obtained at Iquique with the living animal inhabiting them. This beach is elevated 2500 feet above the Pacific." (p. 116.) Also, the presence of a species of Amphipod Crustacean belonging to "a truly marine family," dredged by M. Agassiz in Lake Titicaca at a depth of sixty-six fathoms, indicates that this lake may be a remnant of the Pacific ocean; though it now stands at an elevation of 12,500 feet above the sea.

These facts tend to prove that the Andean plateau during the Quaternary period was paroxysmally elevated into the air some 12,000 feet. Let us now look at the possible results of such an enormous upheaval on the plants and animals of this region. Before and at the time this movement began, when the land was 12,000 feet lower than now, the Atlantic trade winds which now cross Brazil, impinge upon the Andes and drop their moisture on the eastern slopes alone, then favored as well the western slopes and Pacific coast. The tropical flora and fauna now confined to the neighborhood of Guyaquil on the coast of Peru then probably spread over Bolivia, Ecuador, Peru and Chili to Patagonia. The tropical belt in Peru ends with the chinchona forests of Loja, which is 6768 feet above the Pacific ocean. The sugar cane grows in Baños which is about 6500 feet high. At Riobamba, with an elevation of 9200 feet, the climate and vegetation are temperate; here occur bones of the mastodon, horse, deer and llama—animals which may have lived in a temperate climate. But was not their extinction, and that of the colossal sloths, armadillos, and other animals of the pampas largely due to a change of climate resulting from the elevation of the Andean plateau?

As the land gradually rose, the atmosphere would become more rarified and insupportable to tropical life; the animals and plants would either seek lower levels or undergo extinction, or in certain cases become modified into species suited to a temperate climate. As the plateau rose still higher, the air would become too cold and rarified for even the mastodon and horse. Gradually an alpine zone became established, and finally the higher peaks of the Andes, at an elevation of 15,000 feet, became mantled with perennial snow, and on the eastern flanks of Chimborazo, which intercepts the moisture of the Atlantic trades, glaciers established themselves. We thus see how, within Quaternary times, temperate and alpine zones became established over the vast Andean plateau, originally, perhaps at the end of the Pliocene, a plateau of the third order, clothed with vast forests like those of Brazil and Venezuela.

In Patagonia, likewise, the elevation of the Cordillera, and the change of level of the low lands of the eastern coast, now well-known to have happened, are they not sufficient to account for the extinction of the fauna of the pampas?

The same phenomena obtained in Western North America. Throughout the Tertiary period there was in the northern portion of the plateau region a secular rise of land, if not at times paroxysmal, resulting in the drainage of the plateau into the Pacific and the formation of vast inland seas and estuaries which eventually became fresh-water lakes.

During the Laramie epoch the Rocky mountain plateau became dry land, and the elevation and drainage went on during the Eocene. The Gulf of Mexico was much larger in the Eocene epoch than now; afterwards the coast of Texas rose from 300 to 700 feet, while farther north, in Colorado and Wyoming, the Rocky mountain plateau rose from 4000 to points 10,000 feet above the ocean.

The plains east of the Rocky mountains are underlaid by beds deposited by vast inland, fresh-water lakes. In Texas these beds dip under the Gulf of Mexico, but at the base of the Rocky mountains in Colorado they are 7000 feet above the sea. They have been tilted up. Gen. Warren and Mr. King have shown that after the Pliocene epoch such a tilting took place. These lakes dried up, and the marvelously abundant mammalian life which thronged about their shores became extinct as the Quaternary period opened. May not the extinction of life so widespread throughout the West, particularly at the end of the Eocene, the Miocene and the Pliocene, have been mainly due to the great changes in the physical geography of that vast region? We see also why a semi-tropical climate and flora and fauna continued to exist around the Gulf of Mexico, but ceased to live on the elevated Rocky Mountain plateau, as well as the Sierra Nevada and Cascade plateaus. The whole western portion of the continent was carried up bodily, the lakes drained off by the Missouri, Columbia and Colorado rivers and the air at such an elevation becoming rarified, dry and cooler, the tropical life became either extinct or migrated southward to warmer and lower regions. Towards the end of the Pliocene multitudes of llamas, droves of horses, mylodons, elephants and mastodons, with lions, cats and dogs, flourished in Oregon, Montana, Utah, Wyoming, Colorado and New Mexico; changes of level and consequently of climate were perhaps the main factors concerned in their demise.

There were throughout the Tertiary most widespread and all pervading geological changes, culminating in the upheaval of the two great mountain chains of the West. Horizontal Cretaceous strata lie on the Rocky mountains at an elevation of 10,000 feet, the sign and proof of an extensive upheaval. We know that the movement in South America, while gradual for the continent, was more or less locally paroxysmal. Was it not the case also in North America?

By the end of the Pliocene, North America assumed its present continental proportions. The Rocky mountains and Sierras shot their peaks into the sky to elevations of 10,000 and 15,000 feet above the Pacific. These great walls shut off the moist trade winds from the Pacific, a period of dessication set in throughout the great basin between the Rocky mountains and Sierra Nevada, and extensive rainless districts resulted. But even then there were alternate wet and dry cycles throughout the early Quaternary. Great Salt Lake, from being a vast body of fresh water, became a shallow brine pool; the sources of the Colorado, Columbia and their tributaries likewise partially dried up.

Finally, the Glacial epoch came in, the glaciers invaded Northeastern America; these on the one hand, and the great elevation of the western plateau, seem to have been the causes which removed the Pliocene fauna; which removal was, geologically speaking, comparatively sudden.

Either at the end of the Pliocene or beginning of the Quaternary, as seen by the bones in the Port Kennedy cavern described by Professor Cope, there was a singular mixture of what we now regard as tropical and temperate forms living so far north as Pennsylvania; with the tapir, peccary, Mylodon, Megalonyx, Castoroides and sabre-toothed tiger, were apparently associated the deer, bison, horse, porcupine, raccoon, dog, weasel and smaller mammals. The fauna was in part extinguished by the glacial cold, Port Kennedy being situated a little south of the edge of the great glacier.

The result of a change of climate was a change in the nature of the forests; the tapir and peccary were forced to migrate southward; the colossal sloth and sabre-tooth tiger died outright; the Castoroides, horse and mastodon lingered through the Glacial epoch, their remains being found at the bottom of swamps, but above the glacial and river drift; while the deer, bison, raccoon, dog or wolf, and other forms survived with unimpaired vigor and became adapted to a lower climate, forming the typical members of the north temperate fauna of America.

Farther south, in the river gravels and caves of the Middle and Southern States, are found the bones of the great sloths, Megatherium, Megalonynx and Mylodon, the American lion and bear; these were possibly swept out of existence by the cooler winters of the Mississippi valley, which was free from ice, but probably had from their proximity to the great glaciers a lower climate than in Pliocene times.

Professor Cope remarks; "Since the Eocene, the mammalian fauna of the northern hemisphere has diminished in number of species and genera. The Eocene fauna was richer than the Miocene, the Miocene than the Pliocene, and the Pliocene than the modern fauna." There is certainly a significant parallelism between the widespread changes in the physical geography of North America, the differentiation of climates and of faunal areas, and the increasing extinction of life.

The West Indies meanwhile were the scene of notable changes in the distribution of land and sea. From being much larger, and in some cases connected perhaps with South America, they became submerged. Cope has described the fossil remains found in a cave on the Island of Anguilla. Out of twelve species of mammals, seven are extinct and several were chinchillas of large size.

About the shores of the Mediterranean there were remarkable changes in the relations of land and sea. The species of dwarf and other elephants whose bones have been discovered on the Island of Malta, show that within recent times that island must have been connected with the main African continent.

In the old world, simultaneously with the mountain-building of America, the Alps during the later Pliocene attained their present proportions; the Himalayas rose to their present heights; the continents of Asia, with Europe, and of Africa assumed their present outlines.

The extent and nature of the changes which took place late in the Pliocene in the physical geography of the globe were without doubt much greater than at any previous time in the history of our planet. While the present coast lines were being established volcanic agencies were widespread and powerful, and over what were then regions of intense volcanic activity are to be now seen but the dying embers of subterranean fires.

The long, quiet preparatory eons of the Mesozoic and early Tertiary, were succeeded by a crisis in geological history, just as the comparative quiet of the Palæozoic age terminated in the widespread disturbances which took place at the end of the Coal period.

If we glance back through the geological ages we shall see that there were cases of the comparatively rapid extinction of types or whole groups of animals. The more remarkable were the extinction of the trilobites and ammonites. Darwin remarks: "The extermination of whole groups, as of ammonites toward the close of the secondary period, has been wonderfully sudden."

In the same manner the trilobites as well as the Eurypterida ceased to exist at the end of the Palæozoic age; the Silurian graptolites disappeared with comparative suddenness; the crinoids and brachiopods mostly, and the dinosaurs and ornithosaurs, as well as pythonomorphs wholly perished during the Cretaceous period.

The views we have presented, while opposed to ultra-uniformitarian ideas, have nothing in common with the Cuvierian catastrophic doctrine of sudden, wholesale extinctions and re-creations. But known facts in palæontology postulate long periods of quiet preparation, succeeded by more or less sudden crises, or radical changes in the physical structure of continents, resulting in catastrophies, both local and general, to certain faunas or groups of animals, as well as individual species.

The biological changes were not due to climatic and geological changes alone, but it should be borne in mind that the great changes, slowly induced but not without striking final results, ending in the addition or loss of vast areas of land, induced extensive migrations, the incursions of prepotent types which exterminated the weaker. The reaction of one type of life upon another, the results of natural selection, were apparent all through; but these secondary factors were active both during periods of quiet and periods of change. Here again we may quote from Darwin, the leader, next to Lyell, of the uniformitarian school, who remarks: "We have every reason to believe, from the study of the Tertiary formations, that species and groups of species gradually disappear, one after another, first from one spot, then from another, and finally from the world. In some few cases, however, as by the breaking of an isthmus and the consequent irruption of a multitude of new inhabitants into an adjoining sea, or by the final subsidence of an island, the process of extinction may have been rapid."

Local extinctions due to local changes of level; the formation of deserts, saline wastes and volcanic eruptions and vast outpourings of lava, such as took place in Oregon and Idaho during the Tertiary, with sub-marine earthquakes causing the death of fishes on a vast scale, these are quite subordinate factors.

In closing this meager sketch of a subject which has not received very much attention, we have endeavored to attract notice to what we have been accustomed to regard as the main factors in the extinction of species and of higher groups. That there is a limit to the age of species as well as to individuals almost goes without saying. As there is in each individual a youth, manhood and old age, so species and orders rise, culminate and decline, and nations have risen, reached a maximum of development and decayed. The causes, however complex, are, in the case of plants and animals, apparently physical; they are general and pervasive in their effects, and have been in operation since life began; there have been critical periods in palæontological as well as geological history, and periods of rapid and widespread extinction as well as a continual, progressive dying-out of isolated species. Such extinction was, so to speak, a biological necessity, for otherwise there would have been no progress, no evolution of higher types.

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EDITORS' TABLE.

EDITORS: A. S. PACKARD AND E. D. COPE.

——In entering upon the twentieth year of the publication of this magazine, the friends of the undertaking may congratulate themselves on its signs of good health and strength, as seen in the portly appearance of the later volumes. Having passed through the perils of infancy and childhood, may we hope that in entering upon years of maturity it will, with each volume, gain in strength and character as an exponent of American natural science.

While the magazine has doubled in size, the number of departments and of assistant editors has correspondingly increased. More space is given to reports of scientific discoveries so as to render the magazine more useful to science-teachers, and the working naturalist.

Our great need is, more numerous plates and cuts; to secure this end our friends are urged to aid in enlarging our subscription list.

Our hearty thanks are due to the public for its support, and to our contributors and assistant editors. Depending on their aid and good will we hope to make the future volumes of the NATURALIST still more deserving of public support and esteem.